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RESEARCH ARTICLE

# First record of the land operculate snail *Cyclophorus pfeifferi* Reeve, 1861 (Mollusca, Cyclophoroidea, Cyclophoridae) from India

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## Abstract

Through the present manuscript, we are reporting for the first time the presence of *Cyclophorus pfeifferi* Reeve, 1861 in India. Previously, this species of land snail was reported only from South-East Asian countries Malaysia, Thailand, Cambodia and Vietnam. The specimens were collected during field surveys in Dampa Tiger Reserve in Mizoram state, India. The presence of *C. pfeifferi* in India reveals the range expansion and long-distance dispersal abilities of the species. Here we discuss the taxonomy, ecology and possible routes of dispersal of the species in India.

## Keywords

Caenogastropoda, dispersal, distribution, north-east, range expansion, South Asia

## Introduction

The land operculate snail genus *Cyclophorus* Montfort, 1810 belongs to the family Cyclophoridae, subclass Caenogastropoda. This genus is one of the largest and diverse groups within the family Cyclophoridae, the fossil record of which dates back to the early Tertiary period (first period of the Cenozoic Era) (Gordon and

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Olson 1995; Egorov and Greke 2007). Globally, there are 180 nominal species reported throughout the sub-tropical and tropical habitats of South and South-East Asia, as well as the southern areas of China, Korea, and Japan (Reeve 1861; Kobelt and Möllendorff 1897; Kobelt 1902, 1908; Gude 1921; Laidlaw 1928; Zilch 1956; Raheem et al. 2014; Nantarat et al. 2014a, 2014b; Tripathy et al. 2018; Do and Do 2019; Sajan et al. 2019a). In India, 46 nominal species of *Cyclophorus* have been described during the colonial period. Most species are restricted in distribution and endemic to different regions in India (Ramakrishna et al. 2010; Tripathy et al. 2018; Sajan et al. 2019a). However, in recent years, the populations of *Cyclophorus* snails appear to have noticeably decreased due to habitat fragmentation, land-use changes and unsustainable harvesting because of their high demand as food resource (Sen et al. 2012; Nantarat et al. 2014b; Tripathy et al. 2018).

The operculate land snail *Cyclophorus pfeifferi* Reeve, 1861 has been previously reported from the tropical rainforests of Penang in Malaysia (Reeve 1861; Laidlaw 1928); Koh Si Chang, Tale Sap, Songkhla and Tak in Thailand (Laidlaw 1928; Nantarat et al. 2014a, b); as well as Muong La and Tuan Giao Districts in Vietnam (Do and Do 2019). However, through the present note we report for the first time the presence of the species in India. Furthermore, we also attempted to discuss the ecology and possible dispersal routes of the species.

## Material and Methods

The Dampa Tiger Reserve (DTR) covers an area of 500 $km^2$ and is located in the Mamit District of Mizoram, India. The topography of the reserve is largely represented by hilly terrain, where the elevation ranges between 250–1100 m. The lowland area vegetation of the reserve is represented by tropical evergreen forest communities, while the highland undulations are dominated by semi-evergreen forests. The annual precipitation of the region ranges from 2000 to 2500 mm, and the average diurnal temperature ranges 12°C–35°C (Devi et al. 2011).

The specimens were collected during the recent field surveys at Damparengpui area in DTR during 2018–19. The active visual search method was used for collection on different macro habitat viz. leaf litter, under stone, woods, decaying logs, and soil following a standard sampling protocol (Emberton et al. 1996, Sajan et al. 2017). Shells of *Cyclophorus* were collected along with other species of molluscs in the families Ariophantidae, Helicarionidae and Pupinidae. The collected dry specimens were washed thoroughly in tap water and preserved directly in container and live specimens of other groups were preserved in 70% ethanol. Specimens were photographed in the laboratory using a Nikon D7000 DSLR camera with an AF-S Micro Nikkor 105 mm VR lens and shell measurements were taken on Mitutoyo dial caliper. Whereas, the distributional map was generated by using QGIS, A Coruña (ver. 3.10.1). The specimens were identified as *C. pfeifferi* based on published illustrations and literature (Reeve 1861; Kobelt 1902; Nantarat et al. 2014b; Do and Do 2019).

The identified specimens were deposited in the National Zoological Collection of Zoological Survey of India (NZSI).

*Abbreviations and acronyms*

AH - aperture height
asl - above sea level
AW - aperture width
DTR - Dampa Tiger Reserve
leg. - legit (i.e. the collector)
NZSI - National Zoological Collection of the Zoological Survey of India
SD - shell diameter
SH - shell height
spm. - specimen
spms. - specimens

## Results

*Systematics:*

Family Cyclophoridae Gray, 1847
Subfamily Cyclophorinae Gray, 1847
Genus *Cyclophorus* Montfort, 1810

Type species. *Helix volvulus* Müller, 1774 [Accepted as *Cyclophorus volvulus* (Müller, 1774)]

*Cyclophorus pfeifferi* Reeve, 1861
(Figure 1A–E)

**Examined material**. India: 1 spm.; Mizoram, Mamit District, DTR, Damparengpui; 23.69461°N, 092.40825°E; 671 m asl; 09 December 2018; leg. Sandeep Kushwaha; within the leaf litter; NZSI M.32735/9 : 2 spms.; Mizoram, Mamit District, DTR, West Phaileng; 23.68477°N, 092.39947°E; 930 m asl; 21 May 2019; leg. Sonam Jahan; from forest floor; NZSI M.33528/9 : 12 spms.; Mizoram, Mamit District, DTR, 23.700505°N, 092.432161°E; 382 m asl; 24 May 2019; leg. Deepti; from forest floor; NZSI M.33527/9.

**Diagnosis**. The species of the genus *Cyclophorus* are mainly differentiated based on shell size, shape and sculpture on the shell surface. The shape of the peristome and umbilicus are considered important diagnosis characters for species identification (Kobelt and Möllendorff 1897; Kobelt 1902, 1908; Gude 1921; Laidlaw 1928). The identification of the *Cyclophorus pfeifferi* is based on the wide and rounded aperture, thickened peristome, distinctly reflected and folded back (Reeve 1861; Do and Do 2019).

**Description**. Shell large, thick, conically turbinated with elevated spire, chocolate brown in colour with a dark brown band below the periphery; apex pointed, suture impressed and convex; shell rather obsoletely keel at periphery that continues up to the peristome, body whorl rounded and stout; 5¼ whorls, rounded, that regularly increase; aperture large, rounded, slightly oblique, and expanded; peristome orange in colour, thickened and distinctly reflected and folded back; umbilicus deep and partially covered by the outer peristome.

**Measurements**. SD 44.40–55.10 mm, SH 35.20–42.00 mm, AH 25.90–33.30 mm, AW 26.70–34.10 mm (n=9).

## Discussion

This is the first record of *C. pfeifferi* from India, expanding thus the geographical range of the species from South-East Asia to South Asia (Table 1). The collected specimens of *C. pfeifferi* were identified and confirmed based on morphological diagnosis (Reeve 1861; Do and Do 2019) and distinguished from closely related species *C. tuba* (Sowerby, 1842), and *C. speciosus* (Philippi, 1847) based on size, last whorl and peristome characters (Figs 1F–G). Recent phylogenetic studies confirmed that *C. pfeifferi* is closely related to *C. affinis* Theobald, 1858, although *C. affinis* is easily distinguished based on its smaller size and simple peristome (Nantarat et al. 2014b).

*Cyclophorus* species prefer a moist environment with relatively lower temperature, and they are predominately active through the rainy season during the day time, crawling on the forest floor, tree trunks and leaves (Vermeulen 1999). *Cyclophorus pfeifferi* has been reported from tropical rainforests in Indo-Burma biodiversity hot-

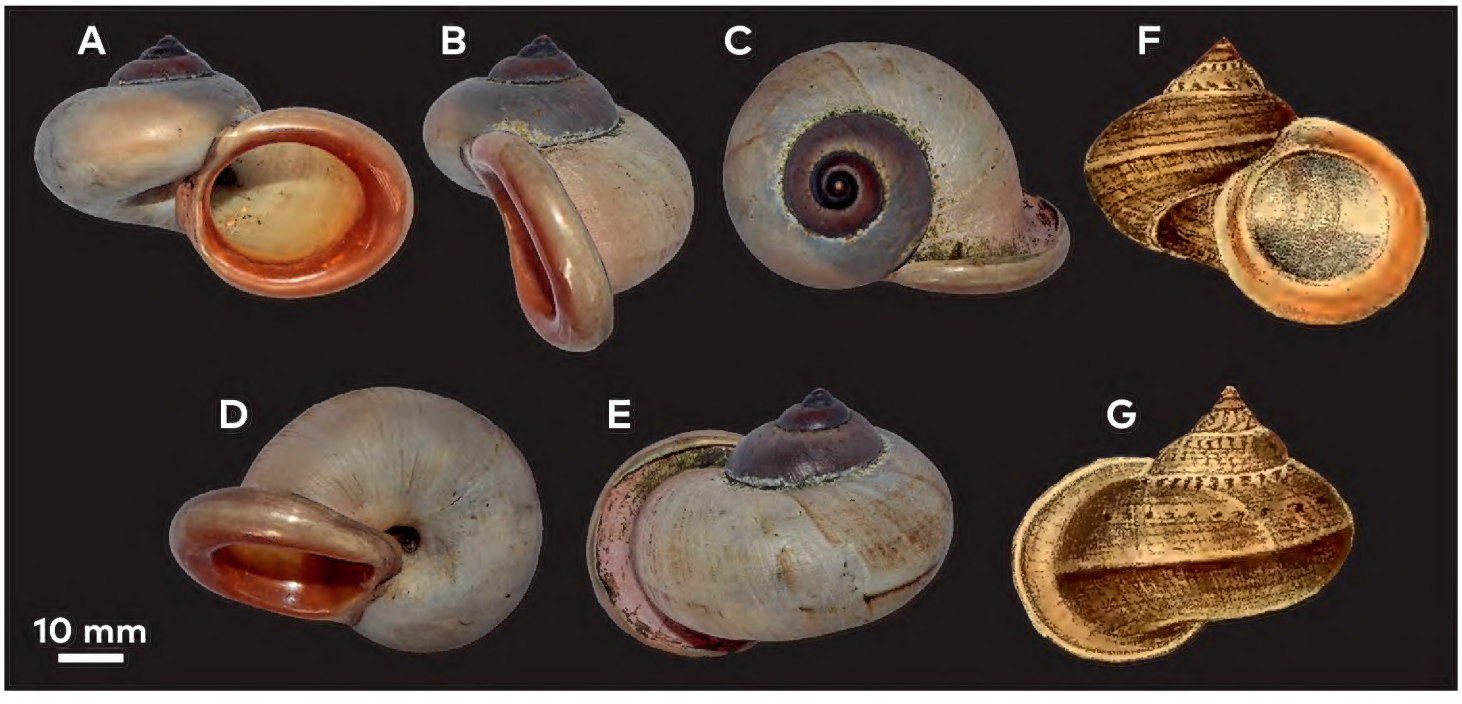


**Figure 1**. *Cyclophorus pfeifferi*. **A–E.** Apertural, apical, umbilical and abapertural view, NZSI M.32735/9. **F–G.** Apertural and abapertural view (illustration adopted from literature after Reeve, 1861).

spot, from the moist environments in Malaysia, Thailand, and Vietnam, in between the altitudinal range of 100–800 m asl (Reeve 1861; Nantarat et al. 2014a, b; Do and Do 2019), with a single record below the minimum range (Laidlaw 1928). The tropical rainforests characterized by Pan et al. (2013), with annual mean temperature of ~20–25°C, annual precipitation >1500 mm and canopy height of 25–50 m seem to be the suitable habitat for *C. pfeifferi*. The new record from DTR occupies a similar forest and habitat with previous records (Figs 2 and 3). The shells of *C. pfeifferi* were collected from the floor and under the moist leaf litter of the tropical evergreen forest that presents similar climatic features. This may indicate that *C. pfeifferi* prefers these kinds of ecological features.

Geographically, the north-eastern region of India is part of the Indo-Burma Biodiversity Hotspot and the Mizoram-Manipur-Kachin rainforest ecoregion (Myers et al. 2000; Olson et al. 2001). The latter has a rich biodiversity and acts as a transitional zone for edge species viz. *Cyclophorus affinis* Theobald, 1858, *C. theobaldianus* Benson, 1857, *C. aurantiacus* (Schumacher, 1786), *C. speciosus* (Philippi, 1847), *C. perdix roepstorffiana* Godwin-Austen, 1895, *C. expansus* (Pfeiffer, 1851), *C. spironema* (Pfeiffer, 1854), *C. pyrotrema* Benson, 1854, *C. pearsoni* (Benson, 1851), *C. bensoni* (Pfeiffer, 1852), and *C. zebrinus* (Benson, 1836). However, species *Cyclophorus affinis*, *C. aurantiacus*, *C. theobaldianus*, *C. zebrinus*, *C. bensoni*, *C. expansus* and *C. speciosus* have long-distance dispersal abilities within

**Figure 2**. Forests and habitat of *Cyclophorus pfeifferi* in Dampa Tiger Reserve, Mizoram, India (Photograph by LKS).

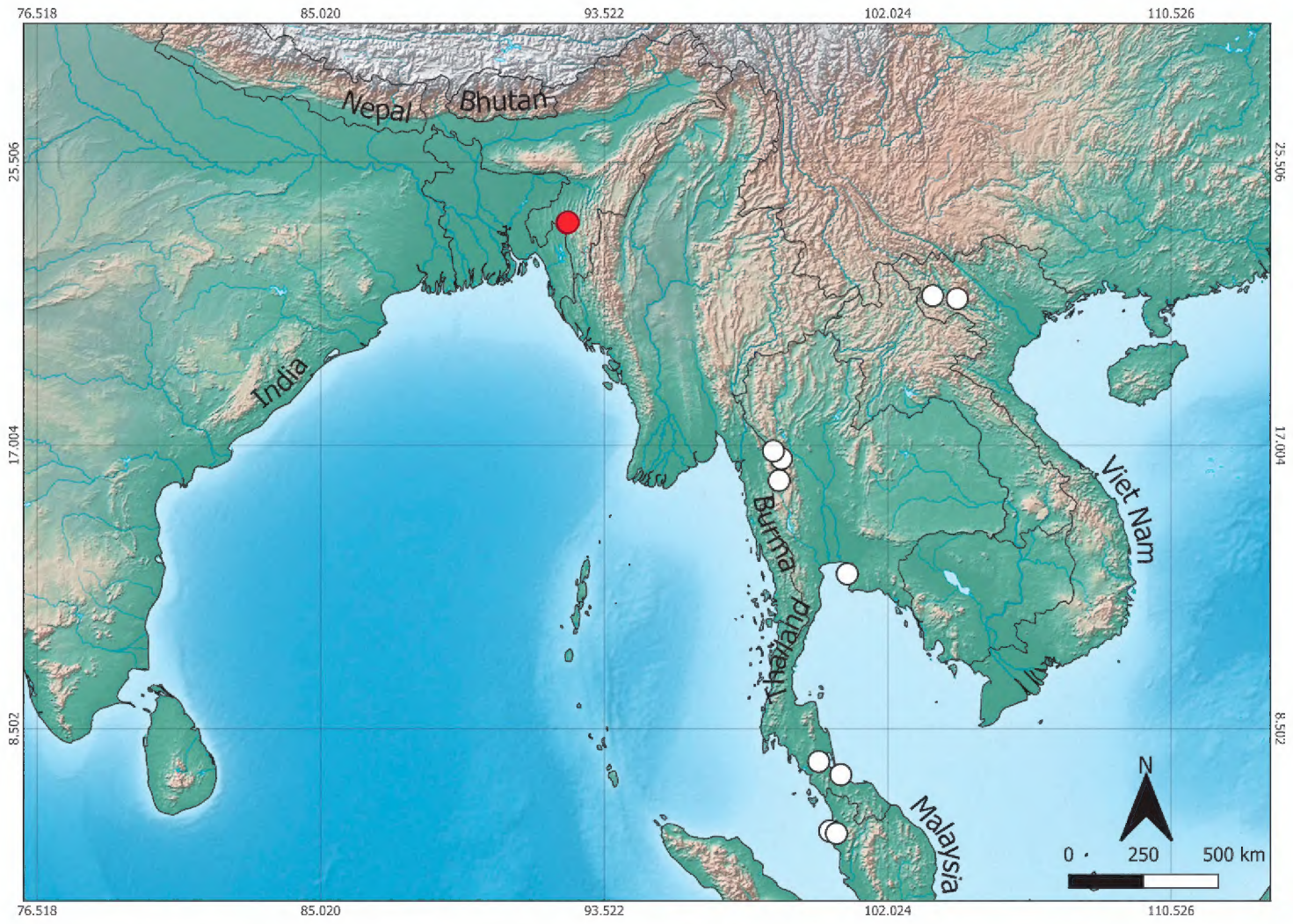


**Figure 3**. Distribution pattern of *Cyclophorus pfeifferi* in South and South-east Asia, where white dots shows the previous record and the new record from India is represented by the red dot (see distributional table).

tropical rainforests from South to South-East Asia (Gude 1921; Ramakrishna et al. 2010; Nantarat et al. 2014b; Tripathy et al. 2018; Do and Do 2019). Moreover, continuous mountain ranges and forest connectivity may act as highways for movement and dispersal (Aubry et al. 2006; Rayfield et al. 2016). The recent record of the Burmese land snails *Oxytesta shanensis* (Godwin-Austen, 1883) from Namdapha Tiger Reserve, Arunachal Pradesh, and the current record may help towards understanding the long-distance dispersal ability of terrestrial gastropods, and connectivity patterns between the existing eco-regions in the Indo-Burma hotspot (Myers et al. 2000; Olson et al. 2001; Sajan et al. 2019b). However, attention towards and conservation of lesser known invertebrate species are apparently very low as compared to the actions towards vertebrate fauna. Also, the land-use changes, habitat fragmentation, urbanisation, and habitat shrinkage are the major causes for serious decline of the molluscan populations. In our landscape survey, the increase in shifting cultivation (*Jhum*) use, collection of firewood, recurring forest fire and collection of non-timber forest products (NTFPs) from the area were observed. Such activities may threaten the habitats and the species composition. Therefore, further systematic field surveys need to be carried out for better understanding of species composition and coexistence of Malayan fauna.

**Table 1.** Geographical coordinates and known localities of *Cyclophorus pfeifferi* in the South and South-East Asian countries.

| Sl. No. | Species | Locality | Latitude | Longitude | Altitude (m) | Reference |
|---|---|---|---|---|---|---|
| 1 | *C. pfeifferi* | Island of Pulo-Penang, Malaysia | 5,4324 | 100,2851 | 339 | Reeve 1861 |
| 2 | *C. pfeifferi* | The 90th km., road No.105, TAK, Thailand | 16,6059 | 98,8326 | 770 | Nantarat et al. 2014a |
| 3 | *C. pfeifferi* | Doi Hau Mod mountain, TAK, Thailand | 15,9495 | 98,7646 | 673 | Nantarat et al. 2014a |
| 4 | *C. pfeifferi* | Vietnam, Son La Province, Muong La District, Muong Bu Commune, entrance of the Tham Bo Cave | 21,4008 | 104,1022 | 715 | Do and Do 2019 |
| 5 | *C. pfeifferi* | Vietnam, Dien Bien Province, Tuan Giao District, Chieng Dong Commune, Po Village, Pu Hong Cay mountain area, near Tham Pua Cave, Sparsely vegetated limestone rock | 21,4907 | 103,3712 | 511 | Do and Do 2019 |
| 6 | *C. pfeifferi* | Mae Sot District, Tak, Thailand | 16,8372 | 98,5911 | 191 | Nantarat et al. 2014b |
| 7 | *C.* (*Salpingophorus*) *pfeifferi* | Koh Si Han [Koh Si Chang], Thailand | 13,1524 | 100,8096 | 27 | Laidlaw 1928 |
| 8 | *C.* (*Salpingophorus*) *pfeifferi* | Penang, Malaysia | 5,3642 | 100,4850 | 324 | Laidlaw 1928 |
| 9 | *C.* (*Salpingophorus*) *pfeifferi* | Tale Sap, Thailand | 7,5171 | 99,9492 | 139 | Laidlaw 1928 |
| 10 | *C.* (*Salpingophorus*) *pfeifferi* | Singgora [Songkhla], Thailand | 7,1213 | 100,6122 | 264 | Laidlaw 1928 |
| 11 | *C. pfeifferi* | Damparengpui, Dampa Tiger Reserve, Mizoram, Mamit District, India | 23,6946 | 92,4083 | 671 | This study |
| 12 | *C. pfeifferi* | West Phaileng; Dampa Tiger Reserve, Mizoram, Mamit District, India | 23,6848 | 92,3995 | 930 | This study |
| 13 | *C. pfeifferi* | Dampa Tiger Reserve, Mizoram, Mamit District, India | 23,7005 | 92,4322 | 382 | This study |

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**Appendix 1.** Detailed morphometric measurements of the shells *C. pfeifferi* collected from DTR (n=9), where, other specimens has been partially damaged and not included in the measurements.

| Sl. No. | Species | Locality | SD | SH | AH | AW |
|---|---|---|---|---|---|---|
| 1 | *C. pfeifferi* | Damparengpui, Dampa Tiger Reserve, Mizoram, Mamit District, India (23.69461°N, 92.40825°E, Alt. 671 m.) | 55.1 | 42 | 33.3 | 34.1 |
| 2 | *C. pfeifferi* | West Phaileng; Dampa Tiger Reserve, Mizoram, Mamit District, India (23.68477°N, 92.39947°E, Alt. 930 m.) | 44.4 | 35.7 | 26.8 | 27.1 |
| 3 | *C. pfeifferi* | West Phaileng; Dampa Tiger Reserve, Mizoram, Mamit District, India (23.68477°N, 92.39947°E, Alt. 930 m.) | 50.3 | 38.9 | 30.6 | 30.9 |
| 4 | *C. pfeifferi* | Dampa Tiger Reserve, Mizoram, Mamit District, India (23.700505°N, 92.432161°E, Alt. 382 m.) | 45.7 | 35.4 | 25.9 | 26.7 |
| 5 | *C. pfeifferi* | Dampa Tiger Reserve, Mizoram, Mamit District, India (23.700505°N, 92.432161°E, Alt. 382 m.) | 54.7 | 40.6 | 31.7 | 33.1 |
| 6 | *C. pfeifferi* | Dampa Tiger Reserve, Mizoram, Mamit District, India (23.700505°N, 92.432161°E, Alt. 382 m.) | 48.5 | 39.2 | 28.9 | 28.7 |
| 7 | *C. pfeifferi* | Dampa Tiger Reserve, Mizoram, Mamit District, India (23.700505°N, 92.432161°E, Alt. 382 m.) | 47.9 | 36 | 27.8 | 29.3 |
| 8 | *C. pfeifferi* | Dampa Tiger Reserve, Mizoram, Mamit District, India (23.700505°N, 92.432161°E, Alt. 382 m.) | 46 | 35.2 | 27.5 | 27.7 |
| 9 | *C. pfeifferi* | Dampa Tiger Reserve, Mizoram, Mamit District, India (23.700505°N, 92.432161°E, Alt. 382 m.) | 44.4 | 34.2 | 27 | 27.5 |